Gold Nanoparticles as Sensors for Electrolytes in Sports Drinks

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General Description

Cart demo

"Gold Nanoparticles as Sensors for Electrolytes in Sports Drinks" is a cart demo that demonstrates how the nanotechnology in the form of gold nanoparticles can be used to sense chemical agents. Visitors learn about size and property differences of nanoscale materials and how nanoscale materials can be used for sensing applications. During the program, visitors will experiment with gold nanoparticles and four different sports drinks. Visitors will determine which sports drink contains the highest level of electrolytes.

Program Objectives

Big idea: Gold nanoparticles can be used as sensors. Nanoscale differences in the structures of the different forms give rise to their dramatically different properties.

Learning objectives:

1. Nanoscale gold (gold nanoparticles) interacts with light differently than bulk gold.
2. The color of gold nanoparticle solutions changes as the size of the particles changes.
3. Nanoscale gold can be used for sensing chemical and biological agents.

Main Messages:

[x] 1. Nanoscale effects occur in many places. Some are natural, everyday occurrences; others are the result of cutting-edge research.
[x] 2. Many materials exhibit startling properties at the nanoscale.
[x] 3. Nanotechnology means working at small size scales, manipulating materials to exhibit new properties.

Time Required:

Set-up	Program	Clean Up
45 minutes (includes nanoparticle synthesis)	15 minutes	5 minutes

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Background Information

Definition of terms

Nano is the scientific term meaning one-billionth (1/1,000,000,000). It comes from a Greek word meaning “dwarf.”

A *nanometer* is one one-billionth of a meter. One inch equals 25.4 million nanometers. A sheet of paper is about 100,000 nanometers thick. A human hair measures roughly 50,000 to 100,000 nanometers across. Your fingernails grow one nanometer every second.

(Other units can also be divided by one billion. A single blink of an eye is about one-billionth of a year. An eye blink is to a year what a nanometer is to a meter stick.)

Nanoscale refers to measurements of 1 – 100 nanometers (nm). A virus is about 70 nm long. A cell membrane is about 9 nm thick. Ten hydrogen atoms lined in a row are would be about 1 nm long.

At the nanoscale, many common materials exhibit unusual properties, such as remarkably lower resistance to electricity, or faster chemical reactions.

Nanotechnology is the manipulation of material at the nanoscale to take advantage of these properties. This often means working with individual molecules. *Nanoscience, nanoengineering* and other such terms refer to those activities applied to the nanoscale. “Nano,” by itself, is often used as shorthand to refer to any or all of these activities.

Program-specific background

At the nanoscale, the properties of materials can change from the properties the same materials exhibit at larger sizes. For instance, the color of bulk gold is shiny and gold. If you have a cubic meter of gold, you are a very lucky person, and it appears shiny and gold. If you have a cubic centimeter or cubic millimeter of gold, it still appears shiny and gold. This is due to how bulk gold interacts with light.

At the nanometer scale, bold interacts differently with light, through a process called surface plasmon resonance. Depending upon the specific size and shape of gold nanoparticles, they can appear red, purple, blue, or other colors. The size-depent behavior of materials on the nanoscale is one reason nanotechnology is so exciting!

Materials

Gold Colloid (approximately 20 mL)

(synthesis via preparation described in: McFarland, Adam D.; Haynes, Christy L.; Mirkin, Chad A.; Van Duyne, Richard P.; Godwin, Hilary A. *J. Chem. Educ.* **2004** *81* 544A.)

Gatorade Ice™ (colorless Gatorade™, available at grocery stores)

Pickle juice from Clausen™, or any pickle juice with as little color as possible (available at grocery stores)

Flavorless Pedialyte™ (available at grocery stores)

Powerade™ (any colorless flavor, available at grocery stores)

20-100 1 dram glass vials (available at Flinn Scientific http://www.flinnsci.com/store/Scripts/prodView.asp?idproduct=17447)

20-100 disposable plastic pipets (available at Flinn Scientific http://www.flinnsci.com/store/Scripts/prodView.asp?idProduct=14297)

Deionized Water

Waste Container

Set Up

Time: (45 minutes)

If necessary, synthesize gold colloid. (45 minutes)

Purchase electrolyte solutions from grocery store.

Assemble materials

Program Delivery

Time: (10 min)

Safety:

All materials used in this demonstration are safe. If desired visitors may wear gloves and goggles.

Procedure and Discussion:

Ask visitors a few probing questions about sports drinks: What do they see athletes drink when they need to replenish their liquids? What do they drink when they are outside in hot weather and exercising? What do they lose a lot of when they sweat? Visitors will usually mention sports drinks at some point during the discussion.

After the initial conversation ask visitors which of the four drinks (Gatorade™, Powerade™, pickle juice, and Pedialyte™) will make the best sports drink. Ask them which two they would like to compare.

At this point tell the visitors that we are going to use nanotechnology to test for which sports drink would be the best to drink when dehydrated. Pick up the bottle of gold colloid and explain to them that the liquid contains gold. They will be surprised to see the color and wonder why it is reddish purple and not gold. Explain that when gold is very, very, very small - on the order billionth's of a meter, or nanometer - the way it interacts with light changes from how bulk gold interacts with light. Explain that the gold particles we are using are 12 – 15 nm in size, and when gold is on this length scale it appears reddish purple. The color that the nanoparticle solution appears depends upon the size of the nanoparticles!

We are going to use this fact to test for the amount of electrolytes (salts) in different sports drinks. Sports drinks contain electrolytes, and adding electrolytes to gold nanoparticle solutions causes the nanoparticles to clump together. Thus, as the sports drinks are added, it causes the nanosized gold particles to clump and become bigger. As the effective size of the gold nanoparticles change, the color of the solution will also change.

Hold up the sample vial of gold (about 10 drops) and ask the visitor the value of the gold in the vial. Typical responses will be between $1 and $4. Explain to the visitors that the value of the gold is a fraction of a penny. Tell them that because the gold is so small we need very little of it to use as a sensor. This is one of the advantages of using nanoscale materials.

Now, invite the same visitor to run their experiment. Hand them two vials with 7 to 8 drops of nano gold, and two pipets to use to add electrolytes to their gold. The guest should add one electrolyte solution drop-wise to one of the vials. After each drop have them swirl the vial and then compare the color of the gold to the sample vial. Have them stop adding the drops once the color the gold becomes noticeably more purple. Be sure the visitors keep track of the number of drops added. Have them follow the same procedure with the second sports drink of their choice and second vial of gold.

After both vials have changed color, have the guest compare the number of drops of each electrolyte solution needed to change the color of the gold. Tell them the drink that turned the gold purple with fewer drops contains more electrolytes in the drink. Ask them if they were correct with their prediction of which sports drink had more electrolytes.

Tips and Troubleshooting:

To help with waste you may want to label the plastic pipets to denote which is used with each sports drink.

Common Visitor Questions:

Q1: Why do electrolytes make the gold nanoparticles clump together?

A1: Electrolytes (salts) are made up of two parts (ions), one with positive charge (cation) and the other with negative charge (anion). When electrolytes are dissolved in water, the cation and anion parts split up. Each gold nanoparticle carries a negative electrical charge on its surface due to how it was made, which makes the individual gold nanoparticles repel each other (kind of how two magnets of the same pole push each other apart). As electrolytes are added to the nanoparticle solution, the cations (positive) are attracted to the nanoparticles (negative), and effectively "cancel out" some of the negative charge that prevented the gold nanoparticles from touching. Thus they are able to come together and clump, leading to larger nanoparticles.

Q2: Do scientists use this method to test for electrolytes?

A2: No, there are other ways to test electrolyte levels in a solution. However, gold nanoparticles can be synthesized with different "tags" on their surfaces that allow other things to cause the nanoparticles to clump. For instance, if an antibody to a protein found in cancerous cells is tagged on the surface, then the gold nanoparticles could clump, changing the solution color, when cancer cells were present.

To be filled in further by users as the program is delivered over time.

Clean Up

Time: (3 minutes)
Rinse out each vial well with deionized water.
Throw away used pipets.
Return caps to the sports drinks and remaining gold colloid.

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